analysis methods described in Section 4.0 of this report were then applied to the lifelines and the results are presented in Section 5.0. Section 6.0 identifies future studies that could be undertaken to further qualify the analysis methods and to improve the details of the specific analysis activities. Section 3.0 provides a summary of the study.

As part of the study validation process, the draft results of the study were submitted to the project advisors, see Table 1, for their independent professional evaluation and to the lifeline owners and regulators who provided information for the preparation of the report or the Cajon Pass Inventory report. FEMA also sent draft report copies to a select list of independent reviewers. Each comment received was addressed, and this final report then was prepared and submitted to FEMA.

Table 1
CAJON PASS IMPACTS OF LIFELINE PROXIMITY:
EXPERT TECHNICAL ADVISORY GROUP

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2.3 Chapter 2.0 Bibliography

1. P. Lowe, C. Scheffey, and P. Lam, "Inventory of Lifelines in the Cajon Pass, California", ITI FEMA CP 120190, August 1991.

2. P. Lowe, C. Scheffey, and P. Lam, "Collocation Impacts on Lifeline Earthquake Vulnerability at the Cajon Pass, California, Executive Summary", ITI FEMA CP 050191-ES, August 1991.

3. C. Rojahn and R. Sharpe, "Earthquake Damage Evaluation Data for California", ATC-13, 1985.

3.0 SUMMARY

This report presents a systematic approach to calculate the impacts due to the collocation or close proximity of one lifeline to another during earthquake conditions. Specifically, the collocation vulnerability impact is defined as the increase in the most probable time to restore the lifeline to its intended level of service. The analysis methods proposed are intended to be used in screening analyses that determine which lifelines or lifeline segments are most impacted by the collocation or close proximity of other lifelines. Once the critical locations or conditions are known, it may be equally important to reanalyze them using more detailed analyses to further define the collocation impacts.

The methods proposed are to use the best available information to determine the lifeline damage state, the probability that the damage state or greater will occur, and the time to restore the lifeline to its intended service. Normally, such information is obtained from the lifeline owner/operator. However, a alternative method is proposed when such information is not available from that source.

The alternative method is based on building upon existing earthquake damage information and analysis methods which have been compiled by the Applied Technology Council (ATC). In that manner, the analysis results can be compared with earlier or future studies that use the data base without the need to compare or justify the data base. However, important improvements to the existing ATC data base also are presented.

Collocation impacts can be described in one of two broad terms: 1) the resource impacts (i.e., the increase in personnel, equipment, and material resources) that are required to return the total lifeline system to its needed operating capacity. This is performed in the present method by summing the impacts at each component along the entire lifeline route. 2) the resource impacts at a specific location where multiple lifeline components are located. In both cases, the present method uses the most probable time to restore the lifeline component or system to its needed operating capacity as the appropriate measure of the resource impacts.

The analysis method has been applied to the lifeline systems in the Cajon Pass, California, as a test case. It is clear that the communication, electric power, and fuel transmissions lifeline systems that have the potential for collocation impacts are, in general, not very sensitive to earthquake ground shaking for shaking intensities represented by Modified Mercalli Intensity indices of VIII or less (these are the values found at Cajon Pass for the assumed earthquake event). They are, however, very sensitive to ground movement expressed as fault displacement, landslides, or lateral spreads. Bridges are sensitive to both ground shaking and ground conditions (displacement, landslide, lateral spread, and local liquefactions at their foundation locations).

It is understandable that topographic conditions have led to the routing of lifeline systems into corridors. However, manmade considerations that force the lifeline owners to use the exact same rights-of-way for widely different needs (for example, locating petroleum fuel pipeline and communication conduits next to each other, routing natural gas pipelines back and forth under a railroad bed, and having a mix of lifelines cross the earthquake fault zone at the same location) greatly increases the individual lifeline risks and the complications that will be encountered during site restoration after an earthquake.